Efforts to Ensure Levee Reliability

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  (seepage, erosion, earthquake resistance)
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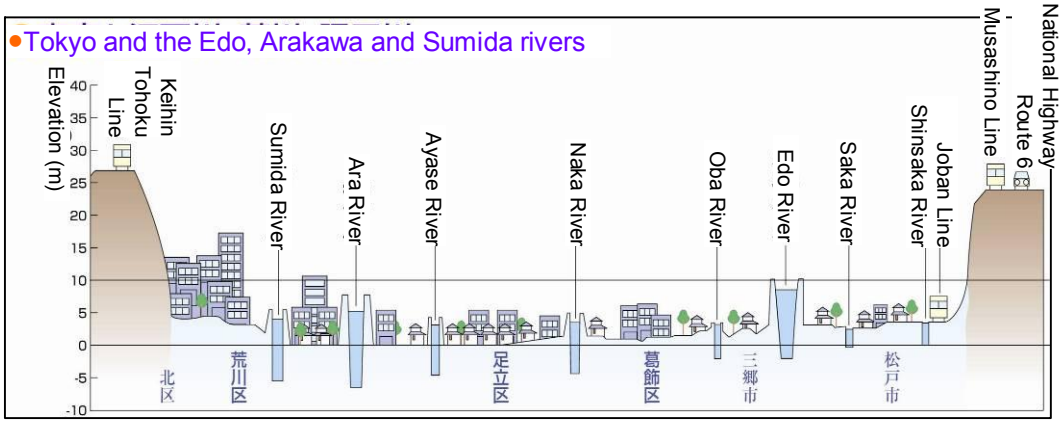
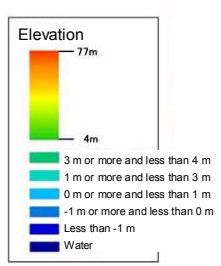
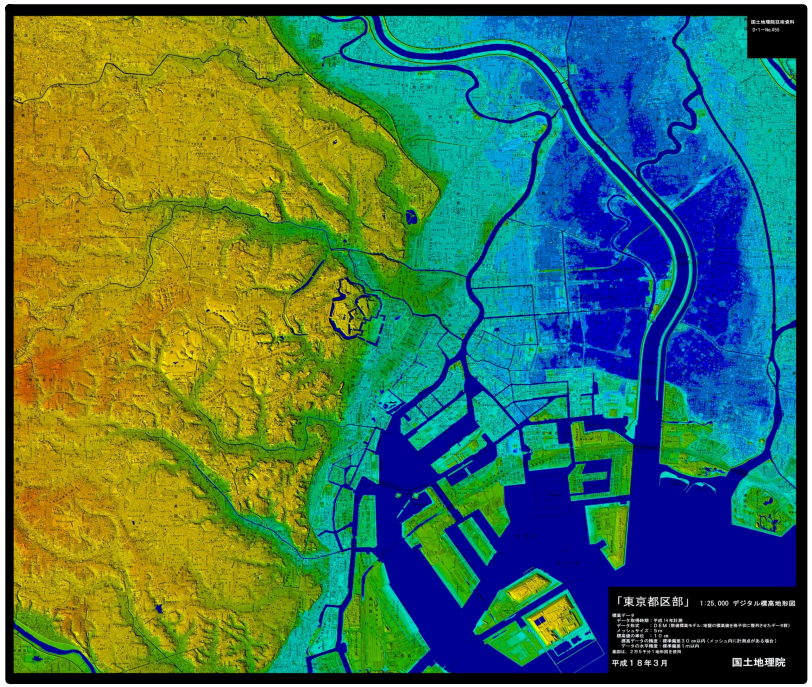
  (feedback from maintenance)

Characteristics of Levees in Japan





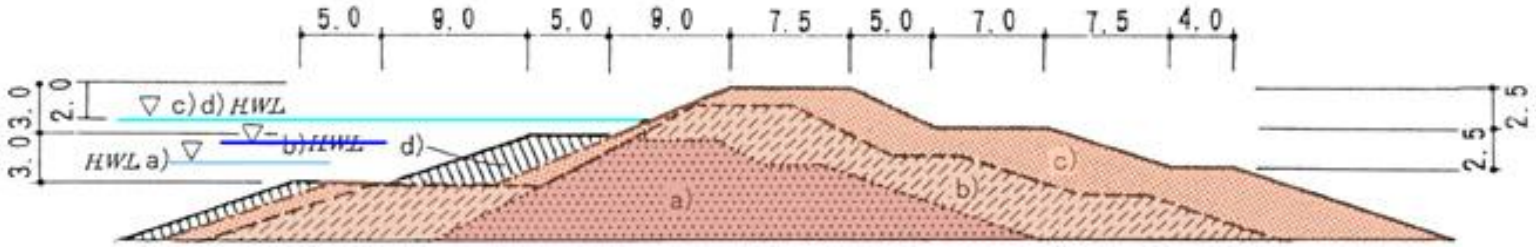
Population and property concentrated in coastal areas and low-lying areas



Source: data compiled by Geographical Survey Institute

Levees as Historical Structures

Levees that we see today are the results of various strengthening works carried out over many years.

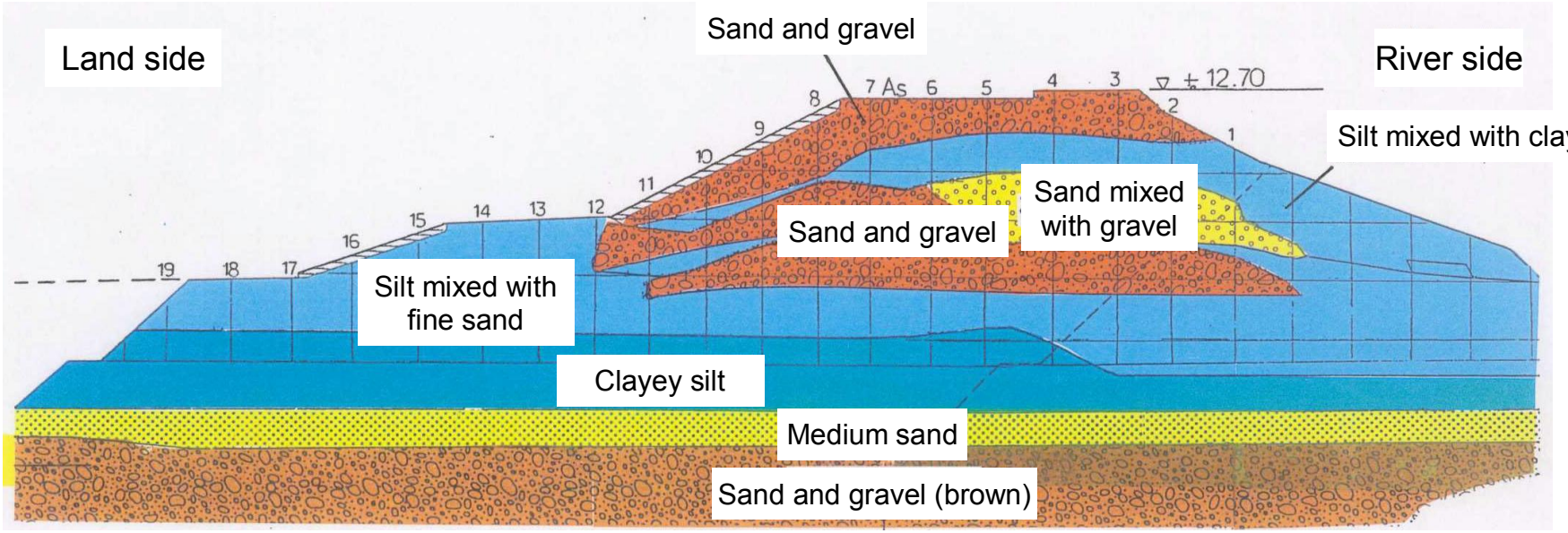


a) Improvement Plan (1911)
b) Augmentation Plan (1939)
c) Modified Improvement Plan (1949)
d) New Modified Improvement Plan (1980)

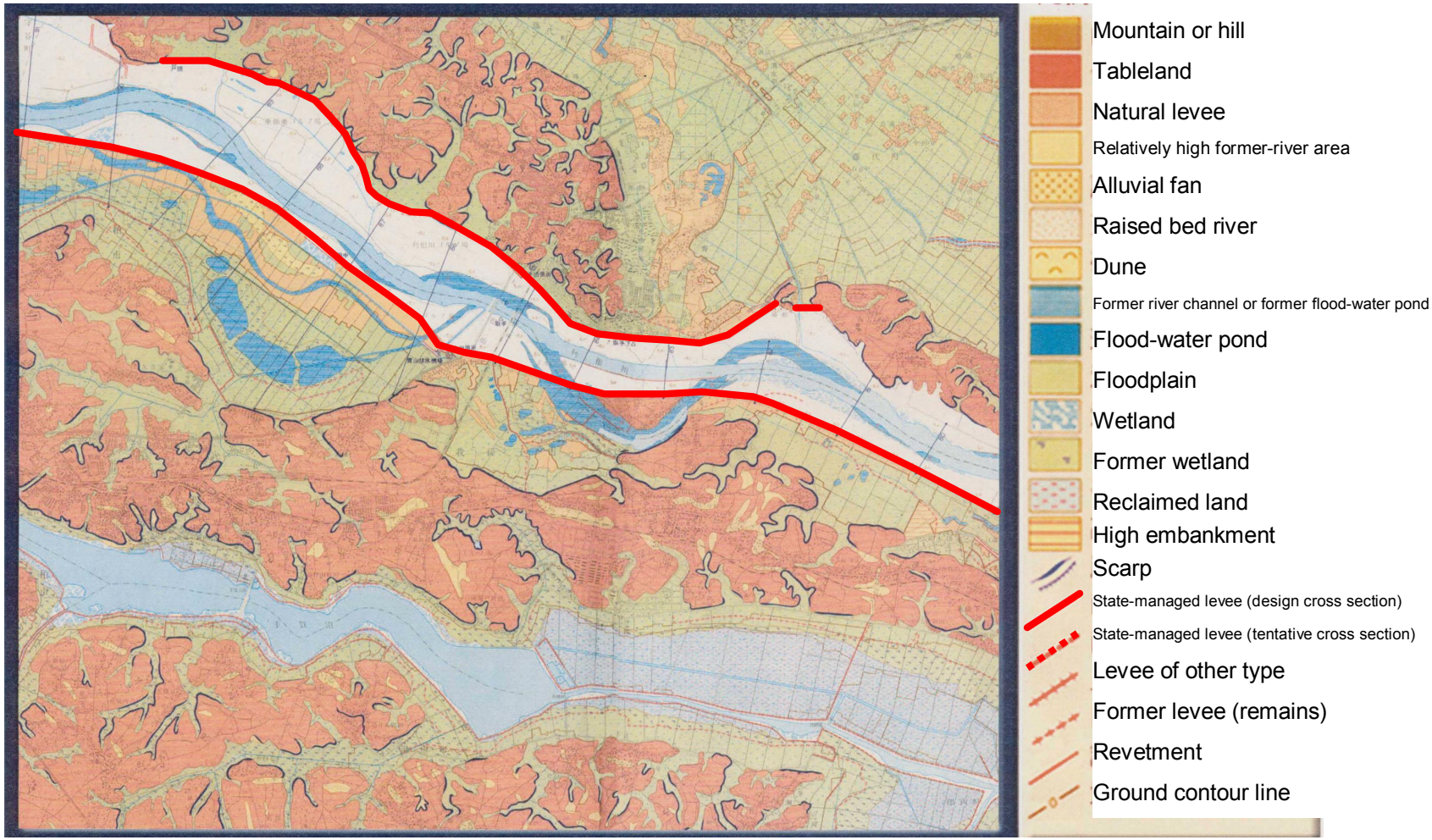
Historical changes in the cross section of the Edo River

Complexity of levee materials

Levees have been built mainly with locally available materials. Consequently, soil types (levee materials) and construction methods (e.g., compaction) used are diverse.



Diverse composition of foundation ground



Example of landform classification map for flood management*
* A map showing details of landform classification in a river area (compiled from 1976 to 1978)

Structural Standards for Levees

- Cabinet Order Concerning Structural Standard for River Administration Facilities, Etc. (Cabinet order, 1976)

  The minimum standards (e.g., height, crest width, slope gradient) for levee geometry appropriate for river sizes are stipulated.

- Technical Standard for River Works (circular of the Director General of River Bureau, revised in 1997)

  Basic concepts for the determination of levee structure based on engineering knowledge are indicated.

- Guideline for Levee Design (circular of the Director of River Improvement and Management Division, 2002)

  Methods for determining levee structure based on engineering knowledge and criteria for verification are stipulated.

- Manual for Determination of Levee Structure (JICE document, 2002)

  Safety verification methods and strengthening methods conforming to the Guideline for Levee Design are described.

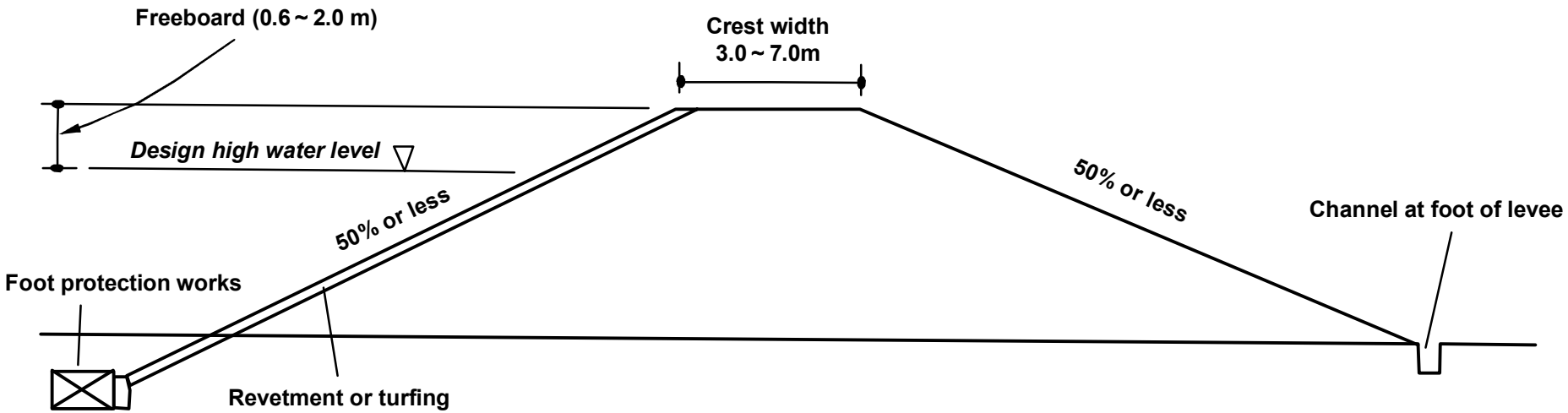
- Guideline for Verification of Seismic Performance of River Structures (circular of the Director of River Improvement and Management Division, 2007)

  Methods for verifying seismic performance against the maximum probable earthquake are specified.

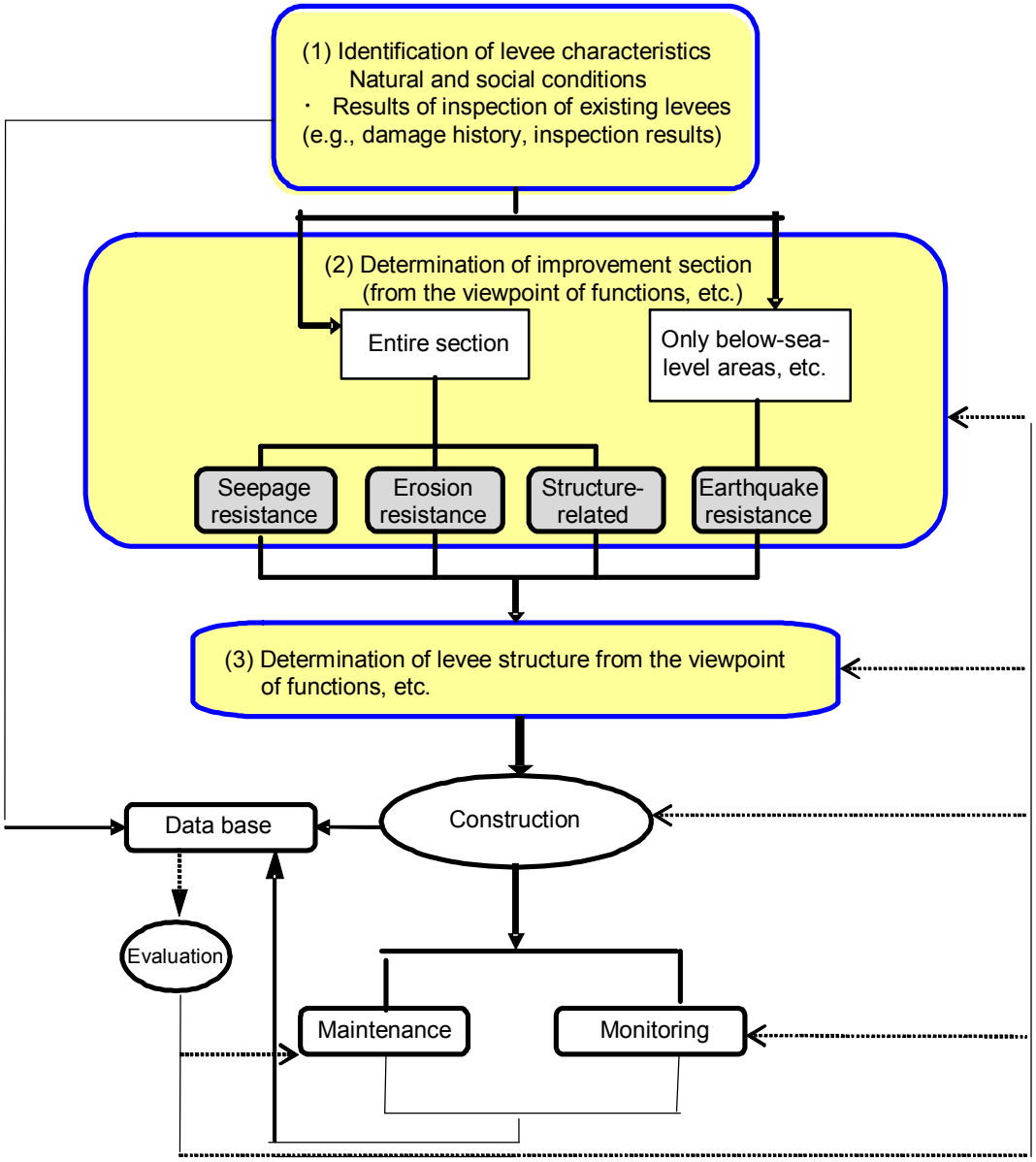
Cabinet Order Concerning Structural Standard for River Administration Facilities, Etc. (geometrical requirements)

- Safe structure against the action of flowing water at or below HWL
- Earth levee (as a general rule)
- Height (height over HWL to be determined according to streamflow)
- Crest width (specified according to streamflow)
- Slope gradient: 50% or less; slope protection by turfing, etc.

Standard Levee Structure Conforming to Cabinet Order Concerning Structural Standard for River Administration Facilities, Etc.



Basic Flow of Levee Design (Guideline for Levee Design 2002)



Summary Inspection of Levee Safety against Seepage (1996 ~)

Safety evaluation procedure

1. Evaluation based on factors

(1) Evaluation from the viewpoint of soil type conditions

Type of foundation ground material	Attention-requiring landform	Type of levee material		
		Clayey	Sandy	Gravelly
Clayey	No	a	c	b
	Yes	b	d	c
Sandy or gravelly	No	b	c	b
	Yes	c	d	c

(2) Evaluation from the viewpoint of external force conditions

Duration of high water level t (hr)	Average hydraulic gradient i					
	Less than 0.10	0.10 ~ 0.15	0.15 ~ 0.20	0.20 ~ 0.25	0.25 ~ 0.30	0.30 or more
$t<24$	a	a	b	b	c	d
$24 \leqq t<48$	a	b	b	c	d	d
$48 \leqq t$	b	c	c	d	d	d

Rating based on factors

(2) Evaluation from the viewpoint of external force conditions	(1) Evaluation from the viewpoint of soil type conditions: a	b	c	d
a	A	A	B	C
b	A	B	B	C
c	B	C	C	D
d	C	C	D	D

2. Evaluation based on damage history

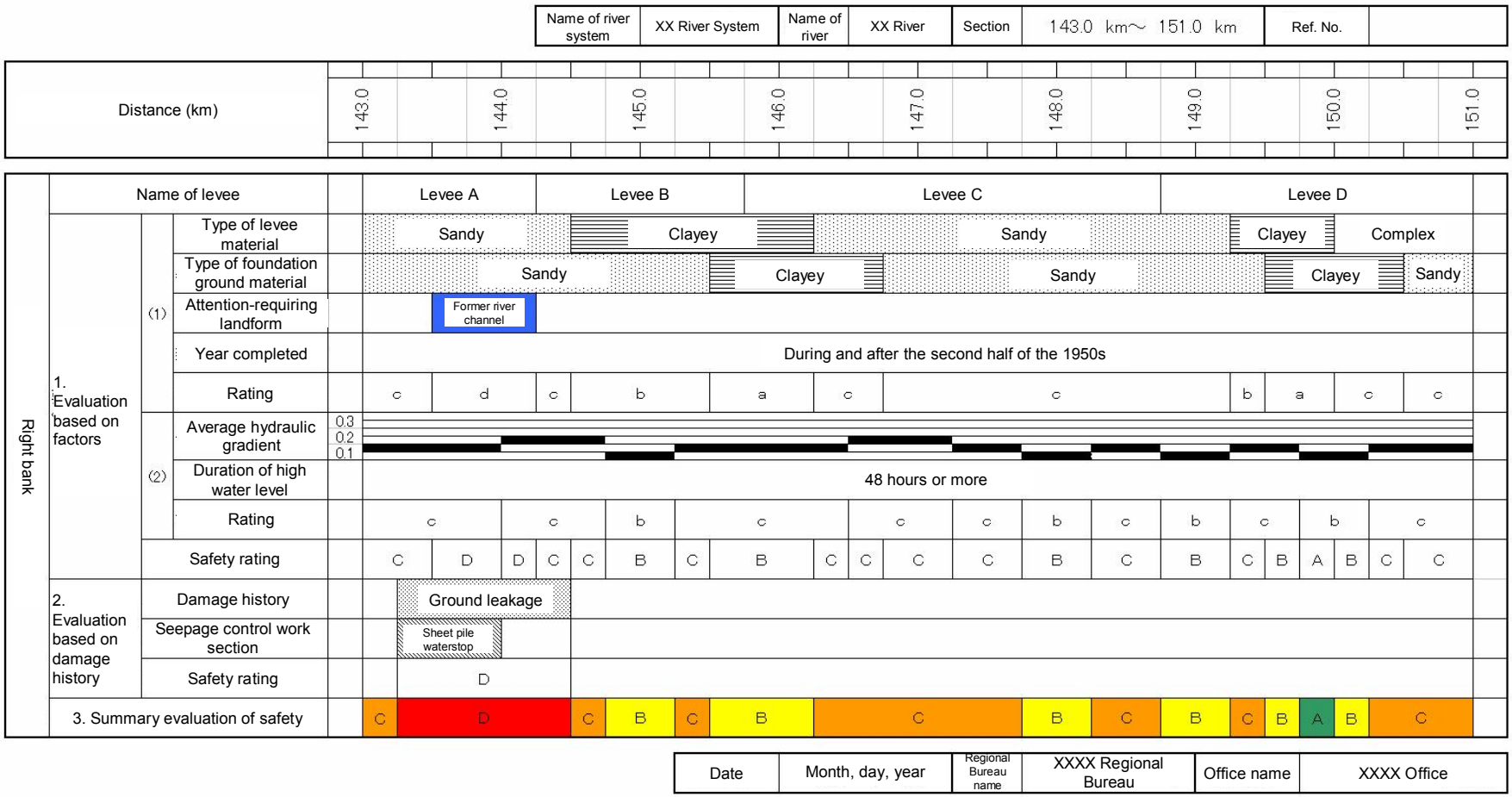
No / Yes — Damage history

- No → Evaluation based on factors: As rated (A, B, C or D)
- Yes → Evaluation based on factors: D regardless of rating

Summary rating safety

A: highly safe
B: moderately safe
C: moderately unsafe
D: highly unsafe

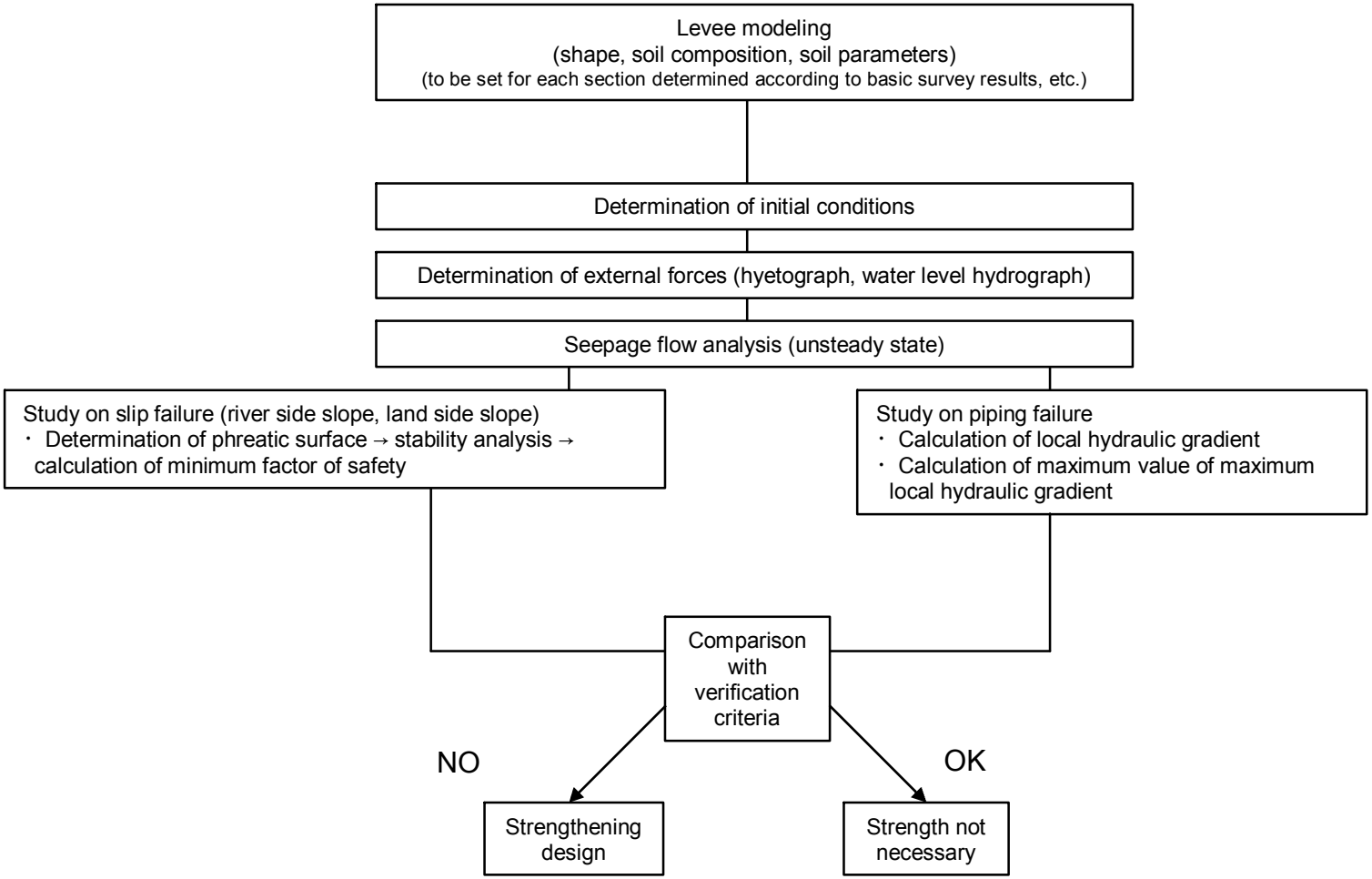
Example of Result of Summary Inspection



Design of Levees against Seepage

Nagara River, 1976

Safety Verification Procedure (for Seepage)



External Forces for Seepage Safety Verification and Verification Criteria

○**External forces for verification**

- River-side water level for verification: design high water level
- Rainfall for verification: rainfall that causes project flood

○ **Verification criteria**

Safety from slip failure

- Land-side slope: factor of safety (Fs) ≧ 1.2 ×α1 ×α2

  α1: overdesign factor for complexity of levee history

  For complex levee history α1 = 1.2

  For simple levee history α1 = 1.1

  For newly constructed levee α1 = 1.0

  α2: overdesign factor for complexity of foundation ground

  If there is damage history or attention-requiring landform α1 = 1.1

  If there is no damage history or attention-requiring landform α1 = 1.0

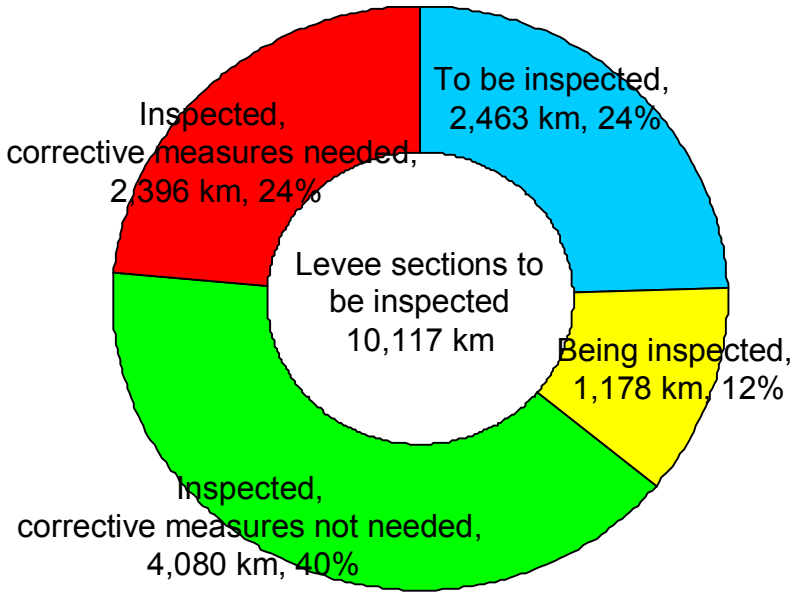
* "For complex levee history": This refers to a case where levee construction began many years ago and has been done in a number of stages or a case where the history of a levee is unknown.
* "Attention-requiring landform": a landform that could result in an unstable state of a levee, such as a former river channel or a former flood-water pond

- River-side slope: factor of safety (Fs) ≧ 1.0

Safety from piping failure of foundation ground

- Without soil cover: maximum value of local hydraulic gradient (i) < 0.5
- With soil cover: weight of cover soil (G) > uplift pressure (W)

State of Levee Inspection for Seepage Safety (State-managed Rivers, 2002 ~)



As of the end of December, 2006

Policy for the coming years

- By fiscal 2009, corrective measures will be taken for levee sections with a combined length of about 50 km that are particularly unsafe and have a history of damage.

- For other levee sections, monitoring activities such as patrol in times of flood will be continued. According to the results thus obtained, efforts will be made to strengthen levees and ensure success in flood-fighting activities.

- By fiscal 2009, the inspection of the remaining levee sections will be completed.

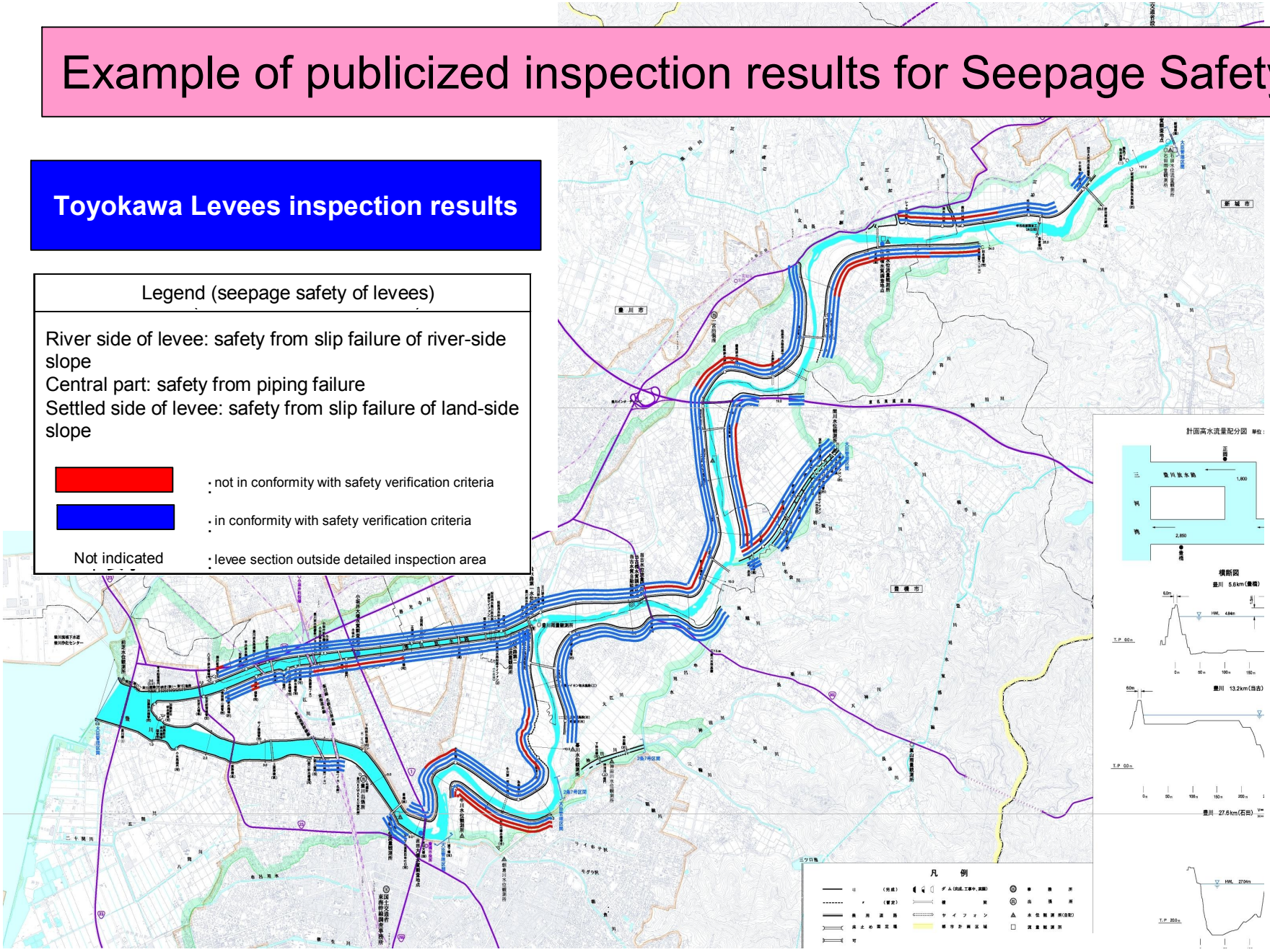
Example of publicized inspection results for Seepage Safety

Toyokawa Levees inspection results

Legend (seepage safety of levees)

River side of levee: safety from slip failure of river-side slope
Central part: safety from piping failure
Settled side of levee: safety from slip failure of land-side slope

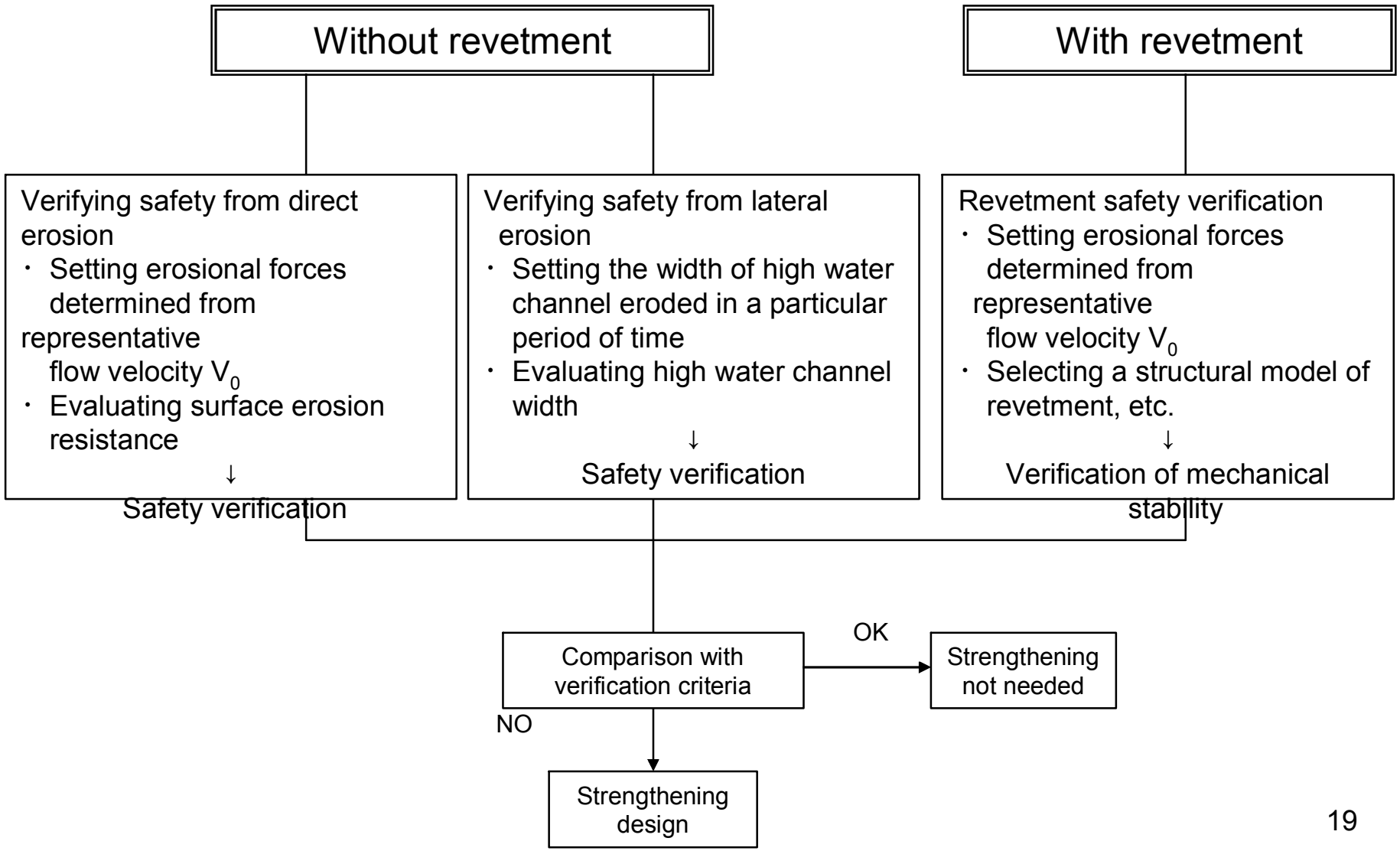
- : not in conformity with safety verification criteria
- : in conformity with safety verification criteria
- Not indicated : levee section outside detailed inspection area



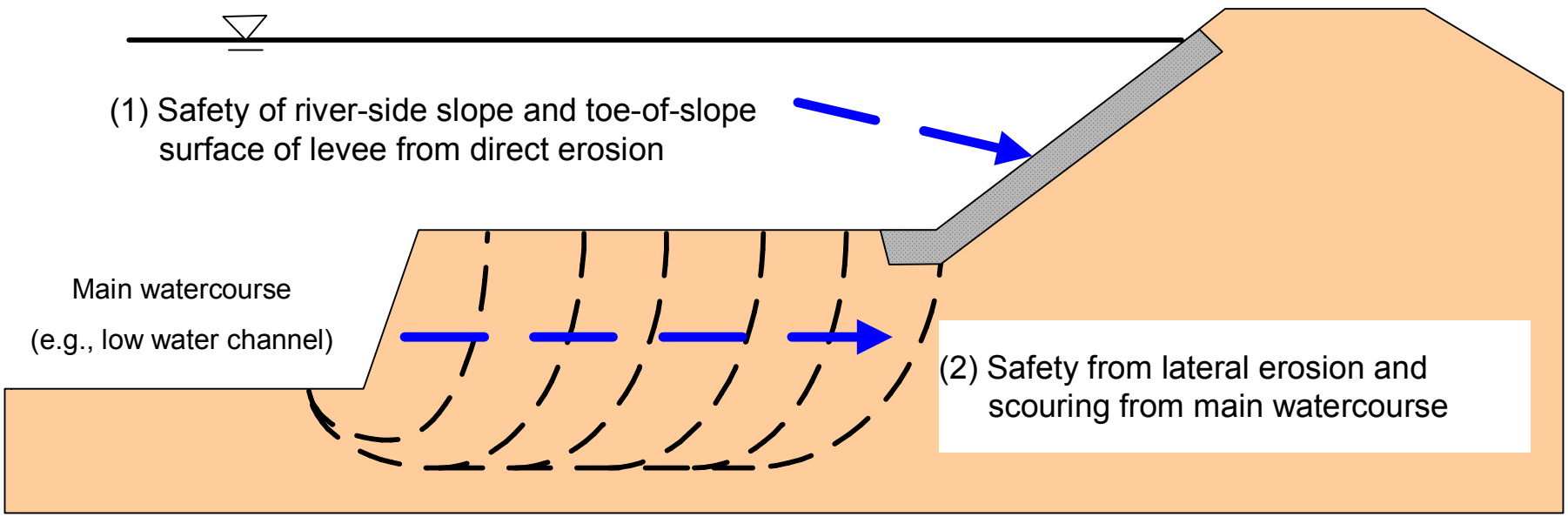
Levee Design against Erosion

Ara River, 1998

Safety Verification Procedure (for Erosion)



External Forces for Erosion Safety Verification and Verification Criteria



External forces for verification

・ Setting representative flow velocity: calculated by multiplying the highest average flow velocity by a correction factor for curvature, etc.

Verification criteria

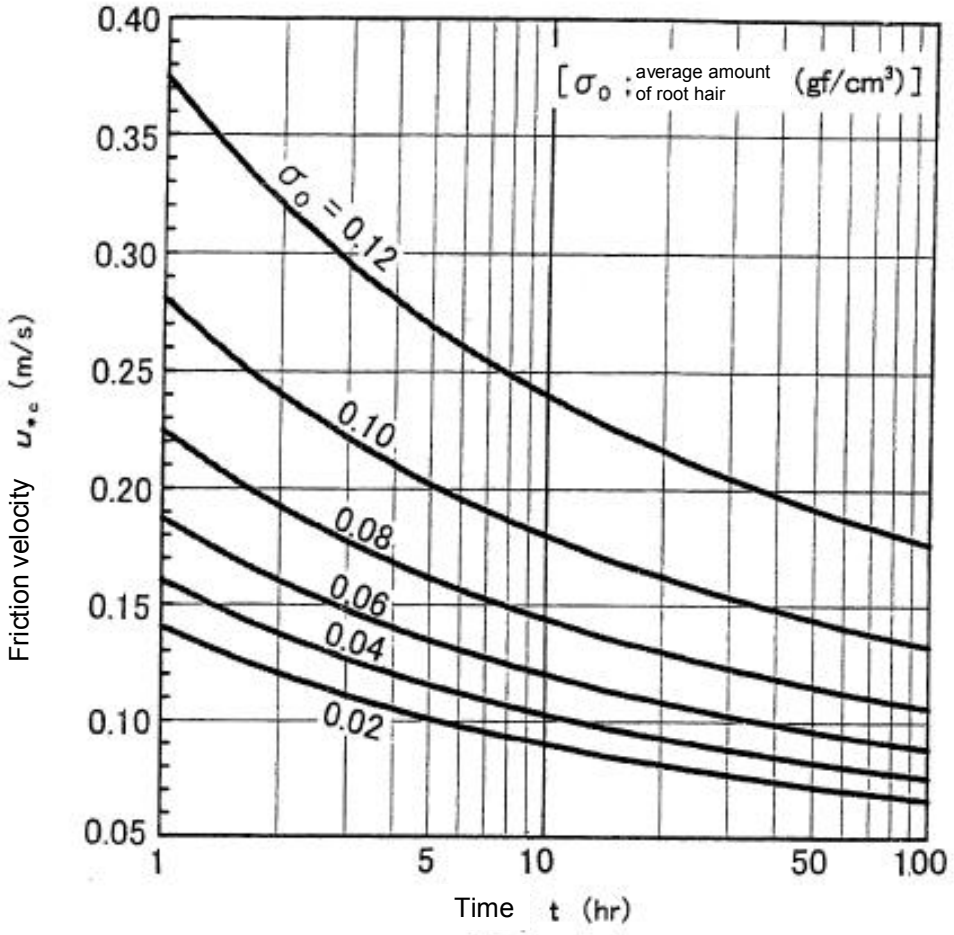
(1) Safety from direction erosion of river-side slope and toe-of-slope surfaces of levee

・ Surface erosion resistance > erosional force calculated from representative flow velocity

(2) Safety from lateral erosion and scouring from main watercourse

・ Width of high water channel > width of high water channel eroded during verification period

Surface Erosion Resistance

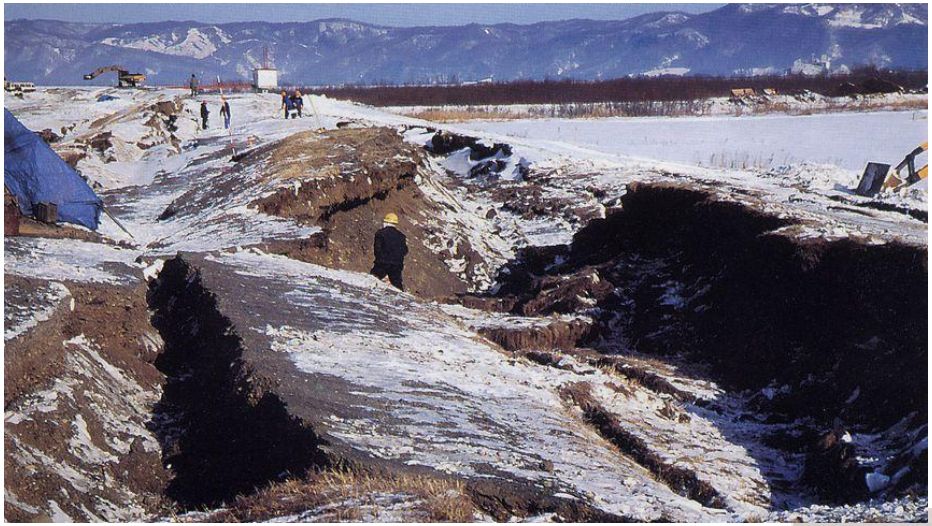


Surface erosion resistance of vegetation
(relationship between the amount of root hair and friction velocity)

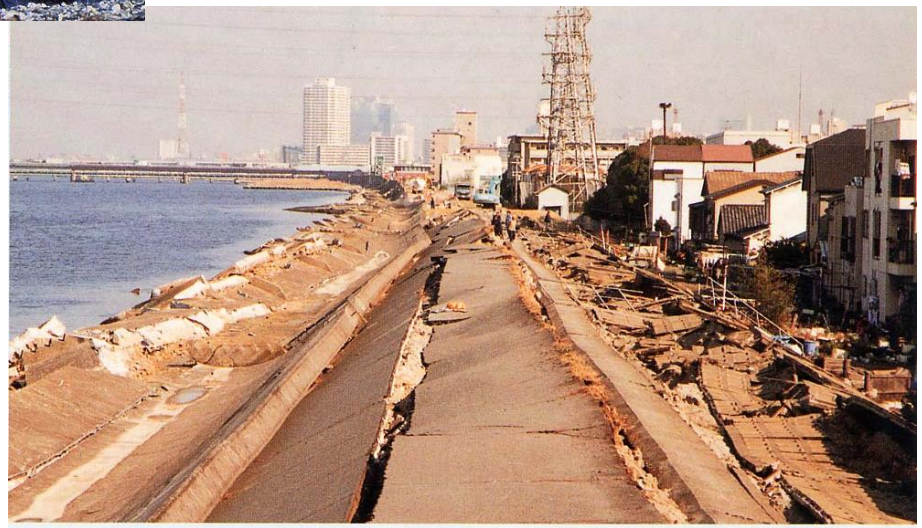
Verification Criteria for Safety from Scouring of Toe-of-slope Surface

River channel segment	Verification criteria (yardstick of width of high water channel eroded by single flood)
1	About 40 m
2-1	High water channel width b > 5 times low water channel bank height H
2-2 and 3	High water channel width b > 2 to 3 times low water channel bank height H

Seismic Design of Levees

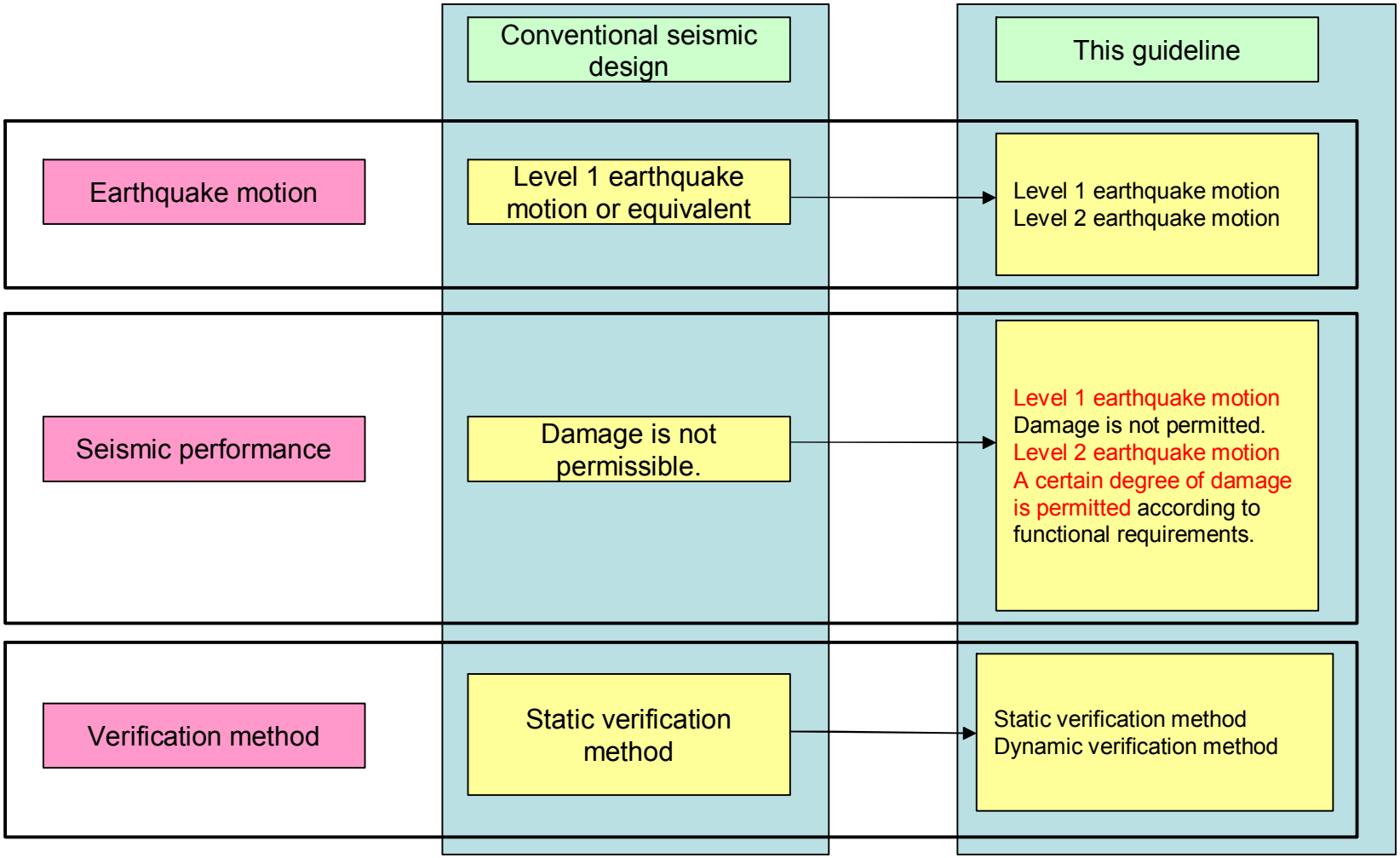


Kushiro-oki Earthquake,
Tokachi River, 1993



Hyogoken Nanbu Earthquake,
Yodo River, 1995

Key Points of the Guideline for Verification of Seismic Performance of River Structures 2007



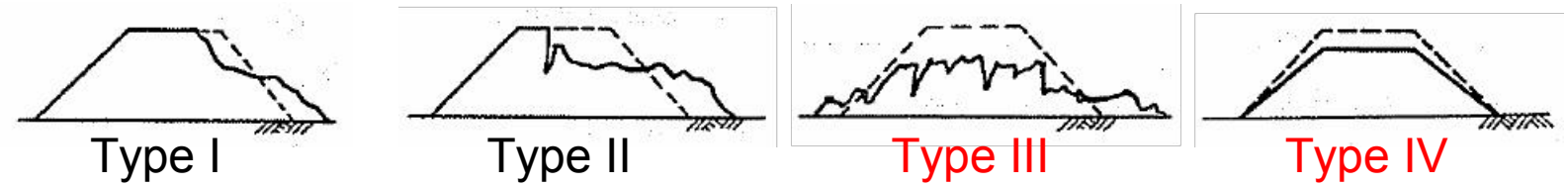
Level 1 earthquake motion: earthquake motion whose probability of occurrence during the service life of a river structure is high

Level 2 earthquake motion: earthquake motion of an intensity that is thought to be the highest, both at the present and in future, at the location of interest

- Level 2-1 earthquake motion: plate boundary earthquake (e.g., Kanto Earthquake of 1923)
- Level 2-2 earthquake motion: inland near-field earthquake (e.g., Hyogoken Nanbu Earthquake of 1995)

Assumed Types of Levee Deformation and Verification Criteria

- Type III and type IV deformations are assumed because the levee crest could become lower than the river-side water level and emergency restoration is difficult to achieve.



- Verification criteria
  - It is confirmed that the post-quake crest level is higher than the river-side water level (maximum water level in normal times) determined for seismic performance verification.

Guidelines for Levee Monitoring

- Guideline for Levee Design (circular of the Director of River Improvement and Management Division, 2002)

- Technical Guideline for Levee Monitoring (circular of the Director of River Improvement and Management Division, 2002)

  Describes standard monitoring methods needed to maintain and enhance the safety and reliability of levees against seepage and erosion at water levels not higher than HWL.

- Technical Document on Monitoring by Visual Inspection (JICE document, 2005)

  Describes concrete monitoring methods, inspection result treatment methods, etc.

Levee Monitoring

○Two purposes

- Identifying weak spots in levees

  Relatively unsafe areas are identified through patrol (visual inspection).

→ Management and information sharing by use of river inspection reports “River Karte” and monitoring information charts by visual inspection

- Verifying levee-strengthening techniques

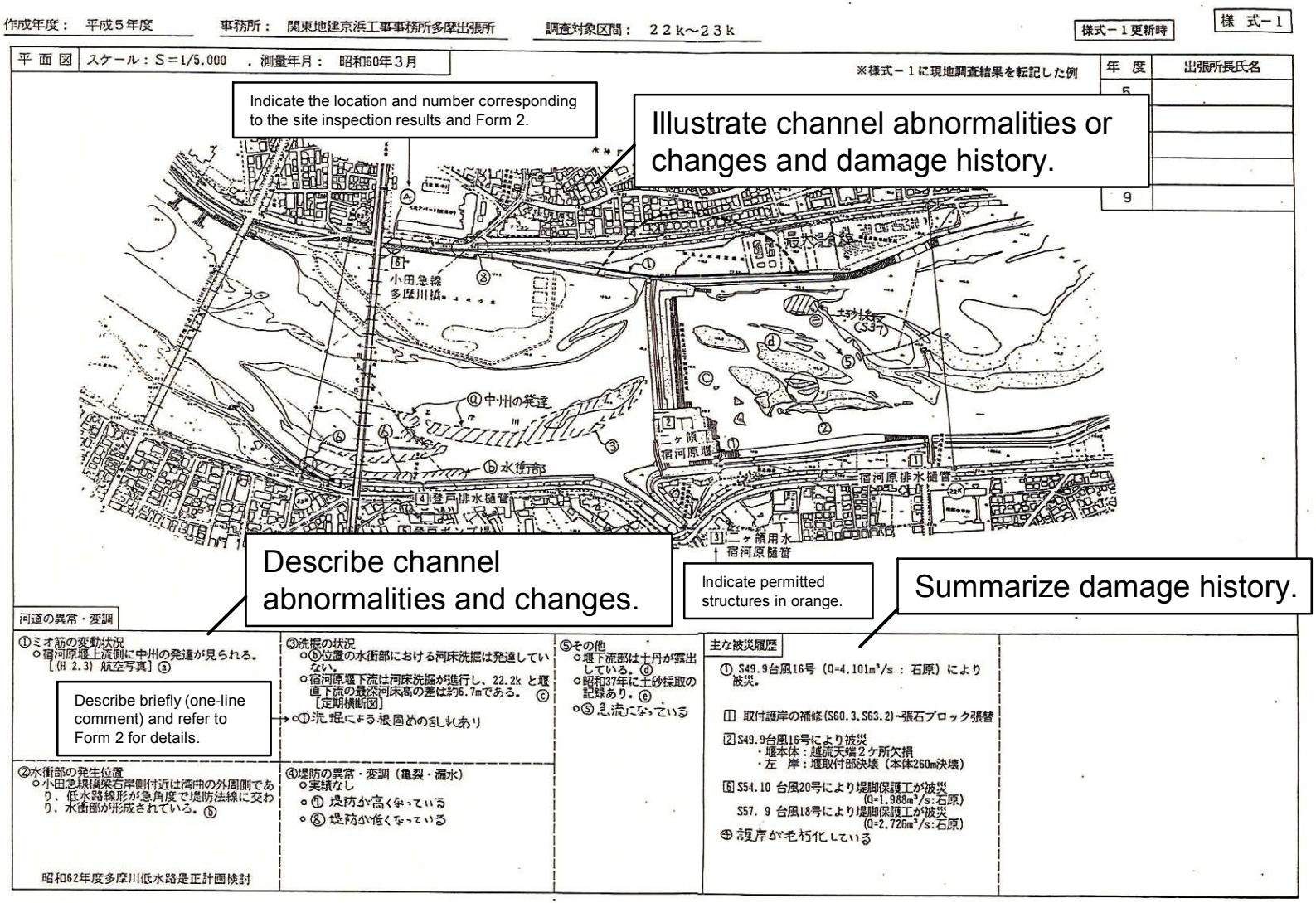
  Mainly by use of measuring instruments, the effectiveness of safety verification methods and levee-strengthening methods is verified.

→Safety and reliability of levees are maintained and enhanced.

Standard Monitoring Items (Partial List)

	During flood	Immediately after flood	In normal times
In river channel		・ Abnormal conditions of groins, vane works, etc.	・ Deep scours in curved sections, areas just downstream of river-crossing structures, etc.
High water channel, low water channel revetments	・ Erosion of high water channel ・ Steps, eddies and bubbles on water surface	・ Erosion of high water channel ・ Abnormal conditions of low water channel revetments, etc.	・ Abnormal conditions of foundations of low water channel revetments
Rive-side slope surface, high water channel revetments, levee revetments	・ Erosion and cracking of slope surfaces ・ Abnormal conditions of revetments, etc.	・ Erosion of high water channel ・ Abnormal conditions of low water channel revetments, etc.	・ Abnormal conditions of foundations of low water channel revetments
Crest	・ Cracks ・ Puddles ・ Cracks at ends of crest pavement	・ Cracks ・ Puddles ・ Cracks at ends of crest pavement	・ Cracks ・ Existence or nonexistence of lower portions, etc.
Land-side slope surface	・ Abnormal conditions and cracking of slope surfaces ・ Leakage in berm areas ・ Muddiness of slope surfaces or berms, etc.	・ Erosion and cracking of slope surface ・ Bulging of slope surface, etc.	・ The state of sodding, stomping by humans and animals, etc.
Land-side slope surface	・ ・	・ ・	・ ・
Channels at foot of levees	・ ・	・ ・	・ ・
Land-side area	・ ・	・ ・	・ ・
Near structures such as sluices	・ ・	・ ・	・ ・

River Inspection Report “River Karte” (Excerpts, Example)



Monitoring Information Chart by Visual Inspection for State-managed Levees (Excerpts, Example)

Monitoring information chart by visual inspection for state-managed levees (results of inspections before and after flood season)

Basic information

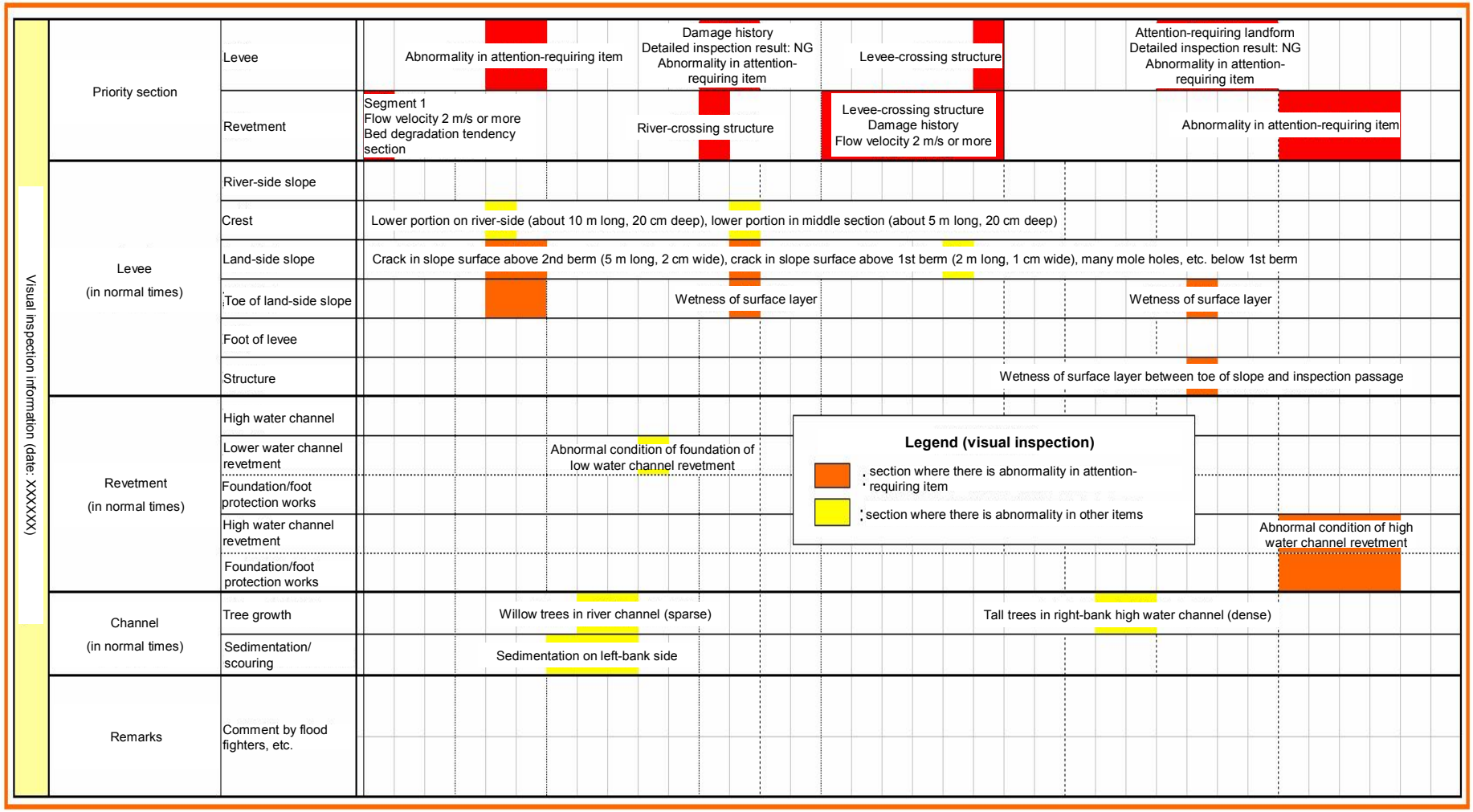
River system name	XX River System	River name	XX River	Section	XX bank XX km to XX km	Management office	XX River Office	Ref. No.	

Category	Item	Sub-item	Entries (distance 46 km → 55 km, left to right)
Basic information – Levee	Distance		46, 47, 48, 49, 50, 51, 52, 53, 54, 55
	Influent/effluent rivers, main structures		Bridge (near 49); Sluice (near 51)
	Basic cross section		Not achieved (46–47); Achieved (47–55)
	Soil type	Levee	c; s; c; c; c; c
		Foundation ground	c; c; c; s; c; c; s; c
	Attention-requiring landforms		Former channel (near 53)
	Year completed		In or after 1955; Before 1955
	Average hydraulic gradient		Less than 0.10; 0.20～0.25; 0.10～0.15; 0.20～0.25; Less than 0.10; 0.10～0.15
	Duration of high water level		48 hours or more
	Damage history and time		Leakage from levee (1969.8)
	Corrective work section and time		Drain (1969)
	Rough rating		A; C; B; D3; C; A; B; A; C; C
	Detailed inspection		★ 2002; ★ 1998; ★ 1998; ★ 2000; ★ 2001
	Detailed inspection results	Riverside	
		Landside	(requiring inspection, near 49)
		Local hydraulic gradient	(requiring inspection, near 49)
		G>W	(requiring inspection, near 53)
Basic information – Revetment	Existence or nonexistence of revetment	High water channel revetment	
		Low water channel revetment	
		Foot protection works	
	Channel alignment		Curved section
	History and time of revetment damage and bank erosion		Bank erosion (1983.7); Failure of low water channel revetment (1980.9)
	Segment 1 section		
	Flow velocity 2 m/s or more	High water channel revetment	
		Low water channel revetment	
	Bank prone to flood-induced erosion		
	Bed degradation tendency section		

Legend (levee inspection)
- ■ : inspected
- ■ : requiring inspection
- ☆ : evaluated cross section
- Year conducted

Monitoring Information Chart by Visual Inspection for State-managed Levees (Excerpts, Example)

Results of inspection before flood season



* Add visual inspection items on an as-needed basis according to characteristics of the river.

Information to be updated every year

Prepare a similar chart after a flood.

Tasks Ahead

Knowledge and important information newly acquired through disaster experience and maintenance activities will be integrated at key locations in a nationwide network. The objective is to built a system for feedback to local engineers.

Enhancing the reliability of levees by improving levee verification techniques and Qualitative improvement technology